

**REMOVAL AND REPAIR OF
EBR-II PRIMARY SODIUM PUMP NO. 1**

**B. C. Cerutti, G. E. Deegan, J. D. Nulton,
W. H. Perry, and R. E. Seever**

**RETURN TO REFERENCE FILE
TECHNICAL PUBLICATIONS
DEPARTMENT**



U of C-AUA-USAEC

ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS
Prepared for the U.S. ATOMIC ENERGY COMMISSION
under contract W-31-109-Eng-38

The facilities of Argonne National Laboratory are owned by the United States Government. Under the terms of a contract (W-31-109-Eng-38) between the U. S. Atomic Energy Commission, Argonne Universities Association and The University of Chicago, the University employs the staff and operates the Laboratory in accordance with policies and programs formulated, approved and reviewed by the Association.

MEMBERS OF ARGONNE UNIVERSITIES ASSOCIATION

The University of Arizona	Kansas State University	The Ohio State University
Carnegie-Mellon University	The University of Kansas	Ohio University
Case Western Reserve University	Loyola University	The Pennsylvania State University
The University of Chicago	Marquette University	Purdue University
University of Cincinnati	Michigan State University	Saint Louis University
Illinois Institute of Technology	The University of Michigan	Southern Illinois University
University of Illinois	University of Minnesota	The University of Texas at Austin
Indiana University	University of Missouri	Washington University
Iowa State University	Northwestern University	Wayne State University
The University of Iowa	University of Notre Dame	The University of Wisconsin

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights.

Printed in the United States of America
Available from

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy \$3.00; Microfiche \$0.95

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

REMOVAL AND REPAIR OF
EBR-II PRIMARY SODIUM PUMP NO. 1

by

B. C. Cerutti, G. E. Deegan, J. D. Nulton,
W. H. Perry, and R. E. Seever

EBR-II Project

May 1972



TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	7
I. INTRODUCTION	7
II. DESCRIPTION OF MAIN PRIMARY-SODIUM PUMPS	9
A. General Description	9
B. Description of Major Subassemblies	13
1. Drive Motor	13
2. Shield-plug Subassembly	14
3. Baffle Subassembly	14
4. Shaft-Impeller Subassembly	14
5. Case-Manifold Subassembly	15
III. OPERATION OF MAIN PRIMARY-SODIUM PUMPS	15
A. Initial Operating History	15
B. Subsequent Operating History	17
C. Recent Operating History	17
IV. REMOVAL OF PRIMARY SODIUM PUMP NO. 1	18
A. Pump-removal Procedure	18
1. Equipment	18
2. Procedure	20
B. Pump-removal Operations	21
1. Preparation	21
2. Removal	21
V. DISASSEMBLY OF PRIMARY SODIUM PUMP NO. 1	25
A. Pump-disassembly Procedure	25
1. Equipment	25
2. Procedure	25
B. Pump-disassembly Operations	27
1. Preparations	27
2. Disassembly	29
3. Examination during Disassembly	31
4. Sodium Cleaning	35
5. Radioactivity Decontamination	35

TABLE OF CONTENTS

	<u>Page</u>
VI. INSPECTION AND REPAIR OF PRIMARY SODIUM PUMP NO. 1	37
A. Replacement of Pump Components	37
1. Lower Bearing and Seal of Drive Motor	37
2. Lower Labyrinth.	37
3. Assembly Bolts	37
4. Pressure Transmitter	37
B. Inspection	38
1. General.	38
2. Comparison.	38
3. Gamma Scan	38
C. Modifications	39
1. Drive Motor.	39
2. Pump Shaft	41
3. Lower Labyrinth.	42
4. Baffle Subassembly	43
VII. REASSEMBLY OF PRIMARY SODIUM PUMP NO. 1	44
VIII. REINSTALLATION OF PRIMARY SODIUM PUMP NO. 1	45
IX. SUBSEQUENT OPERATION OF PRIMARY SODIUM PUMP NO. 1	46
X. SUMMARY	46
APPENDIXES	
A. Cost Analysis for Removal and Repair of Primary Sodium Pump No. 1	48
B. Details of Disassembly of Primary Sodium Pump No. 1	49
1. Pump Containment	49
2. Pump Support.	51
3. Pump Handling	52
4. Conclusions	52
ACKNOWLEDGMENTS	54
REFERENCES	55

LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1.	Reactor Plant	10
2.	Primary Cooling System	11
3.	EBR-II Primary Pump	12
4.	Ball-joint Connector.	16
5.	Pump-removal Assembly	19
6.	Primary-pump Removal Equipment.	22
7.	Pump-removal Equipment in Position	23
8.	Pump Positioned for Disassembly.	28
9.	Removed Lower Labyrinth.	32
10.	Sodium Oxide on Pump Shaft	33
11.	Sodium Oxide in Baffle	33
12.	Seal for Lower Bearing of Drive Motor	34
13.	Interior of Case-Manifold	34
14.	Large Sodium-cleanup Pad in Use during Adverse Winter Weather	35
15.	Sodium Cleaning	36
16.	Radioactivity Decontamination of Case-Manifold	36
17.	Radiation Survey and Gamma Scan of Primary Pump before Cleaning and Decontamination	40
18.	Modified Grease Retainer for Lower Bearing of Drive Motor. .	41
19.	Plugging of Keyway Relief Holes on Pump Shaft.	42
20.	New Modified Lower Labyrinth.	42
21.	Modified Baffle, with Arrows Showing New Drain Holes for Argon Purge Flow	43
22.	Attachment of Lifting Fixture for Reinstallation of Primary Pump	45
23.	Containment, Handling, and Support of Primary Pump during Disassembly	50

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
I.	Design Characteristics of EBR-II Primary Sodium Pump	13
II.	Data on Decontamination of Components of Primary Sodium Pump No. 1	32

REMOVAL AND REPAIR OF EBR-II PRIMARY SODIUM PUMP NO. 1

by

B. C. Cerutti, G. E. Deegan, J. D. Nulton,
W. H. Perry, and R. E. Seever

ABSTRACT

Sodium pump No. 1 in the primary system of Experimental Breeder Reactor II (EBR-II) was removed because of periodic increases in its power consumption with no corresponding changes in primary sodium flow. Before removal, the pump had been operated satisfactorily for over 32,000 hr during an eight-year period. Disassembly of the pump revealed heavy oxide deposits on the pump shaft at and above the lower labyrinth. The labyrinth itself was badly corroded and required replacement. The entire pump assembly was disassembled, cleaned, inspected, and reassembled before reinstallation in the primary tank. Some minor alterations were made to the pump assembly to improve its performance. The most significant alteration was the relocation of the sodium drain holes in the baffle sub-assembly. This change will direct the argon purge in a manner expected to reduce sodium oxide deposits on the pump shaft. Pump operation subsequent to repair and reinstallation has been normal. Shaft torques and power consumption have returned to the levels experienced before pump difficulties developed.

I. INTRODUCTION

EBR-II is an important part of the AEC's Liquid Metal Fast Breeder Reactor (LMFBR) program. Knowledge and experience gained from the operation and maintenance of the facility will be invaluable in the design of future reactors of this type. The EBR-II facility has been described in detail in Refs. 1 and 2.

This report summarizes the recent operating experience and difficulties encountered with primary pump No. 1 and describes the repair of the pump. The procedures for removal, cleaning, and disassembly of the pump are included. The improvements made to the pump during repair should further enhance its reliability. Experience gained from removal

and cleaning of the pump will result in improved procedures and methods for performing similar tasks for major components within the EBR-II primary sodium and in future LMFBR's.

The primary-sodium coolant system at EBR-II removes heat from the reactor core and transfers it to the secondary sodium system. The main primary pumps consist of two Byron-Jackson vertically mounted 5500-gpm centrifugal pumps.

Initial operation of the primary sodium system began in April 1963. Binding occurred in both pumps within their first six months of operation. Failure was caused by excessive rubbing between the pump shaft and the lower labyrinth. Both pumps were removed and modified to eliminate the rubbing. Modification consisted of replacing the pump shafts and relaxing the critical clearances between the shaft and lower labyrinth and baffle plates.

Since initial modification, primary pump No. 2 has performed satisfactorily for over 32,000 hr. Pump No. 1 experienced two incidents of binding after extended periods of reactor shutdown in 1965. The shaft binding was attributed to sodium and/or sodium oxide buildup in the running clearance between the pump shaft and lower labyrinth. After each incident, the shaft was manually rotated by applying approximately 200 ft-lb of torque to begin rotation. The shaft then rotated freely. The pump subsequently performed satisfactorily until mid-1970, when periodic increases in power consumption were noted with no corresponding change in primary sodium flow. Further investigation indicated that excessive torques were required to rotate the pump shaft. Although some success was achieved in providing freer shaft rotation, the pump was scheduled for removal.

Inspection after removal and disassembly revealed a considerable amount of sodium and sodium oxide buildup on the pump shaft, inside the lower labyrinth, and on the shield-plug liner above the labyrinth. Shaft rubbing had occurred in these areas. Sodium oxide had severely corroded the internal serrations of the lower labyrinth. The lower labyrinth was replaced with a unit of improved design, and minor rework was done on the baffle-subassembly drain holes to improve the argon purge in a manner expected to reduce the sodium oxide buildup. The inspection also revealed loss of grease from the lower bearing of the drive motor. To reduce leakage, the grease system for the lower-bearing assembly was changed to increase the reservoir capacity and provide better containment of lubricant. A new bearing with a grease seal was installed.

The removal of the pump from the primary tank required a relatively complex procedure; the pump assembly had to be lifted into an inert-atmosphere enclosure (caisson). Special equipment that had been designed and fabricated for the previous pump removal was again used.

Pump removal was further complicated by the radioactivity of the pump assembly and the adherent sodium (approximately 400 mR/hr at 1 in., maximum). Special precautions were used to limit personnel exposure and to prevent the spread of radioactive contamination.

Partial cleaning and disassembly of the pump were accomplished in a contamination-controlled enclosure within the reactor building. The adherent sodium was allowed to oxidize in air, and the residue was manually scraped sufficiently to permit pump disassembly. The shield plug was first removed and cleaned in a contamination-controlled area within the reactor building. Comprehensive gamma scanning and radiation surveys were performed on the remaining pump assembly and then on the individual pump subassemblies to determine the radioactive species and their distribution. The pump subassemblies were transferred outside the reactor building to the sodium-cleanup pad. Alcohol immersion, followed by hot-water washing, was used to clean each subassembly. Radioactivity decontamination was accomplished by decon-solution immersion and scrubbing. The residual contamination levels, however, required reassembly within a contamination-controlled enclosure similar to that used for disassembly.

After cleaning, the primary-pump subassemblies were returned to the reactor building for inspection and reassembly. Individual subassemblies were again gamma-scanned and radiation-surveyed before reassembly, to determine the effectiveness of the decontamination in the removal of specific isotopes.

After the pump had been reassembled, it was reinstalled in the primary tank with the same equipment without difficulty. Pump operation subsequent to repair has been normal. Shaft torques, pump noise, sodium flow, pump temperatures, and power consumption are at the levels experienced before the pump difficulties developed.

Appendix A gives a manpower and cost summary for removal and repair of primary pump No. 1.

II. DESCRIPTION OF MAIN PRIMARY-SODIUM PUMPS

The two main primary-sodium pumps are located in the primary tank within the containment structure, as shown in Figs. 1 and 2. The operational and physical characteristics are given in the following subsections. A detailed description of the pump assembly appears in Ref. 3.

A. General Description

The arrangement and principal features of the main primary-sodium pumps are shown in Fig. 3. The general design characteristics are given in Table I. Actual operating conditions require these pumps to operate in

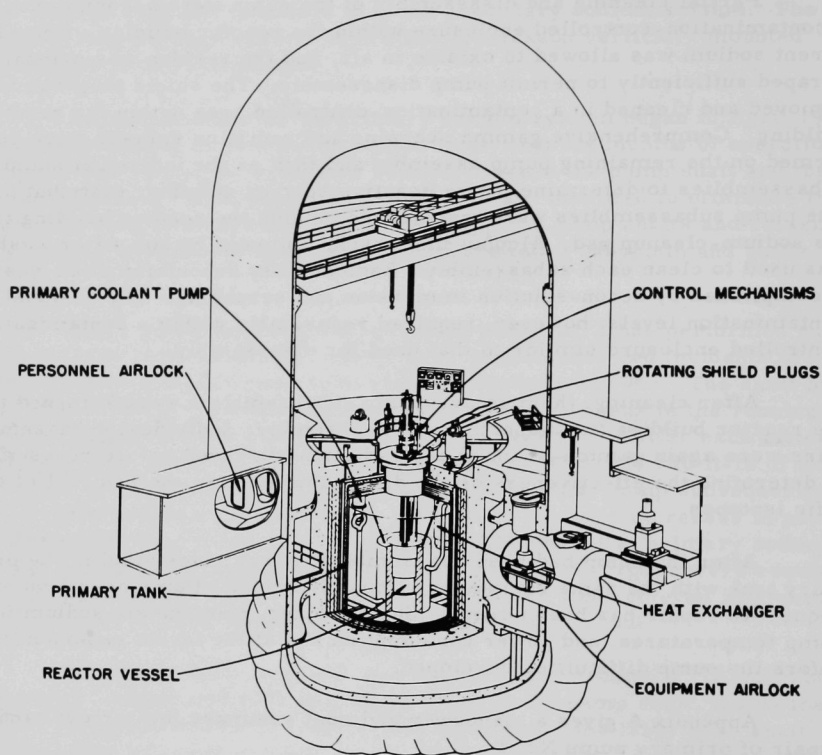


Fig. 1. Reactor Plant. ANL Neg. No. 103-J5488.

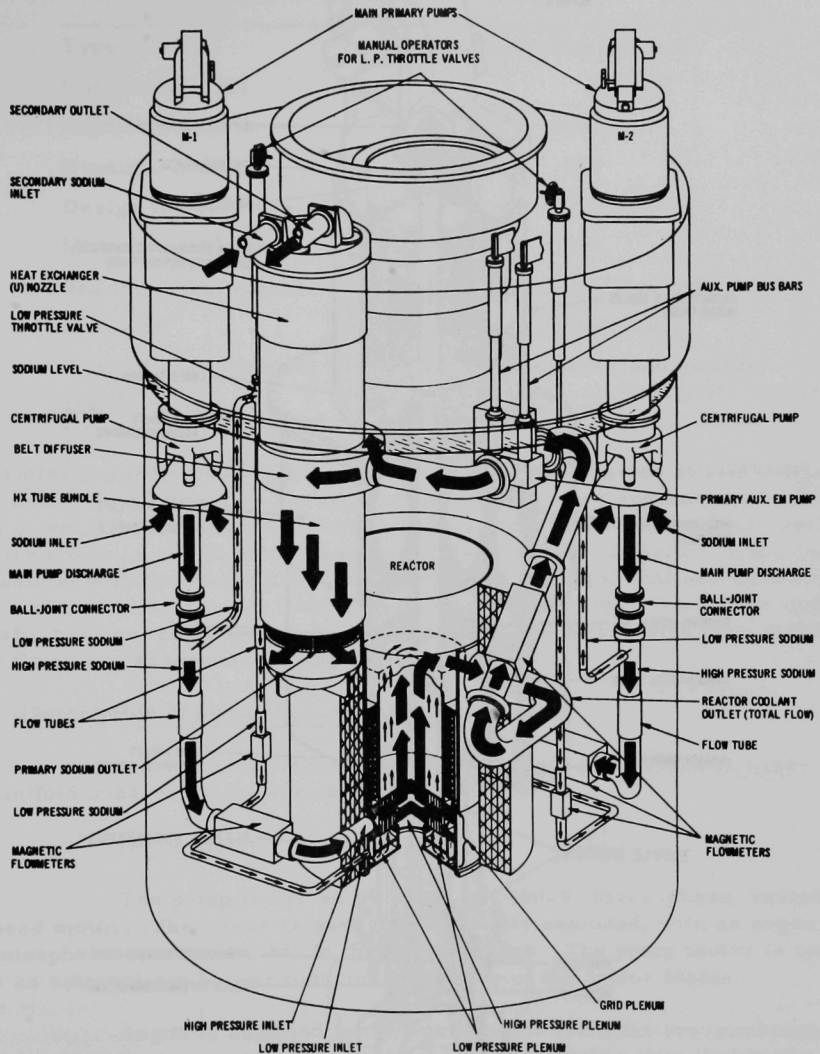


Fig. 2. Primary Cooling System. ANL Neg. No. 103-N5102.

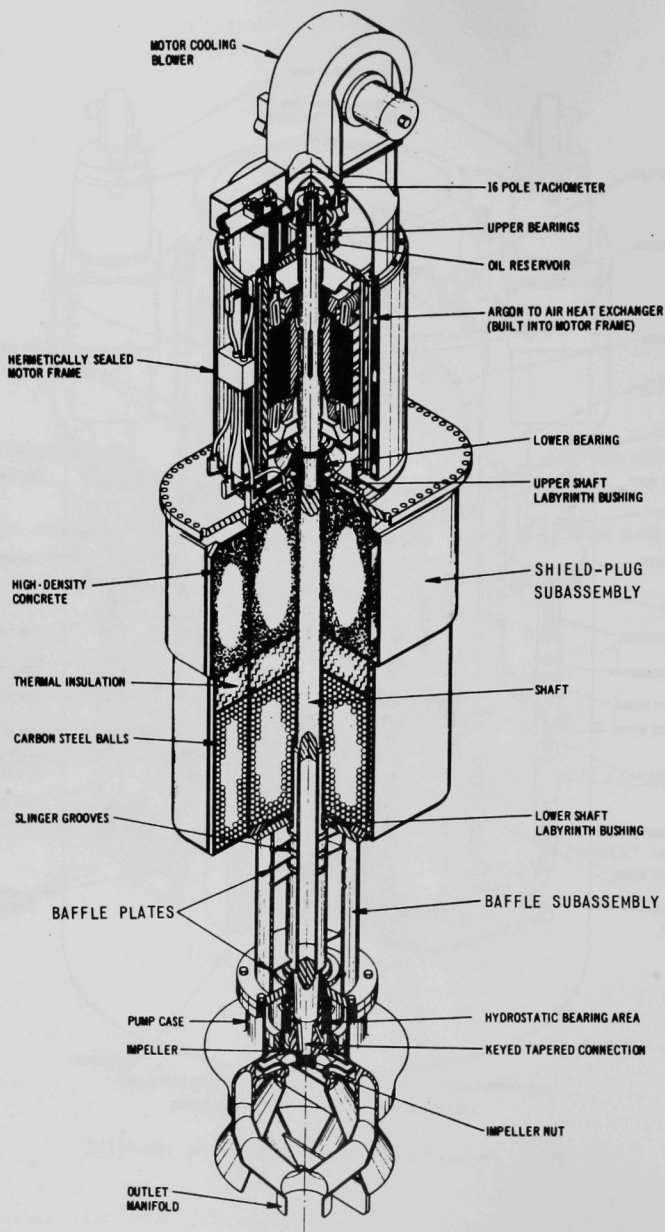


Fig. 3. EBR-II Primary Pump. ANL Neg. No. 103-N5097.

TABLE I. Design Characteristics of
EBR-II Primary Sodium Pump

Type	Mechanical, free surface
Number of units	2
Capacity, gpm	5500
Dynamic head, ft	200
Design temperature, °F	800
Motor speed, rpm	1075
Sealing arrangement	Totally enclosed drive motor
Material	Type 304 stainless steel
Type of speed control	Variable frequency and voltage
Manufacturer	Byron-Jackson

parallel to supply 9000 gpm of 700°F sodium to the reactor at approximately 49 psig. Each pump is a vertically mounted structure approximately 29 ft long, weighing 26 tons. The integral unit consists of a hermetically sealed drive motor, a shield plug, a baffle, a drive shaft and impeller, and a case-manifold with discharge pipe. All portions of the pump that are submerged in sodium are fabricated from Type 304 or 316 stainless steel. The hydrostatic bearing, shaft sleeve (bearing journal), and wear rings have Stellite or Colmonoy hardened wearing surfaces.

B. Description of Major Subassemblies

The drive-motor, shield-plug, baffle, shaft-impeller, and case-manifold subassemblies are described here.

1. Drive Motor

The pump is driven by a 350-hp, 480-V, three-phase, variable-speed motor. The motor is gastight and totally enclosed, with an argon atmosphere common to that in the primary tank. The pump motor is cooled by an external air blower mounted on the top of the motor frame.

Argon is supplied to the pump motor from the low-pressure argon-distribution system at a pressure slightly higher than that of the primary-tank cover gas. The argon flow is adjusted so that a 4- to 6-cfh flow is maintained down the pump shaft. Argon flows down the shaft, through the baffle, and into the primary cover gas through drain holes spaced around the periphery of the baffle. The argon purge prevents the migration of sodium vapor into the motor case and retards the deposition of sodium in the baffle and on the pump shaft.

Ball and roller bearings are used in the drive motor to support and radially constrain all rotating members. The pump shaft and impeller are supported by a radial and thrust ball bearing in the upper end of the motor case and by a radial roller bearing in the lower end of the motor case. The upper motor bearing is lubricated by an oil bath, and the lower motor bearing by grease.

2. Shield-plug Subassembly

The primary-pump shield plug is $6\frac{1}{2}$ ft thick and oblong in section. It supports the pump assembly through the pump-support nozzle of the primary-tank cover and meets the same radiation requirements as the primary-tank cover. The drive motor is bolted to the top flange of the shield plug, and the pump shaft connects to the motor shaft at this location. The pump shaft passes through the center of the shield plug with a $1\frac{1}{4}$ -in. clearance. An aluminum-bronze labyrinth is located at the upper end of the shield plug. A close-running clearance is provided between the pump shaft and the labyrinth. The shield plug is divided into three chambers: the first filled with 33 in. of carbon-steel balls, the second filled with 8 in. of thermal insulation, and the third filled with 34 in. of heavy concrete.

3. Baffle Subassembly

The baffle is located between the shield plug and the case-manifold. It is a cylindrical structure $4\frac{1}{2}$ ft long with approximately 1 ft of the lower section located inside the case-manifold. This internal portion contains the hydrostatic bearing and upper wear ring. The upper section is 20 in. in diameter and contains four baffle plates pitched 3° from horizontal. The pump shaft passes through the center of the baffle plates with adequate clearance to prevent contact. As the liquid sodium climbs the rotating shaft, it comes in contact with three sets of double slinger grooves, which were designed to throw the sodium from the shaft.

The lower labyrinth is located at the top of the baffle and is recessed slightly below the top surface. It is made of aluminum bronze, as is the upper labyrinth. The inside diametral surface of the labyrinth is serrated to lessen the contact area in the event of shaft contact. This labyrinth would aid in preventing shaft seizure if the pump shaft bowed. Self-welding would be less likely to occur between the two dissimilar materials than between two stainless steel surfaces. Both the upper and lower labyrinths minimize the upward flow of radioactive argon gas and contaminated sodium vapor.

4. Shaft-Impeller Subassembly

The shaft-impeller consists of a machined solid and tubular welded shaft with a machined and welded impeller mechanically attached to

the lower end of the shaft. The upper end of the shaft is keyed to the motor shaft, and the shaft-impeller is suspended from the motor shaft by a draw-bolt. There is approximately $3/4$ in. vertical clearance for the impeller inside the case-manifold. The impeller is attached to the pump shaft by a keyed tapered fit with a left-hand-threaded locknut tack-welded on the shaft to prevent the impeller from loosening during operation and thermal-shock conditions. The lower pump bearing is a hydrostatic type and is located directly above the impeller. During operation, a portion of the discharged sodium (approximately 3%) is channeled through the pump case and directed into bearing pockets which surround and force the pump shaft to remain centered. Colmonoy pads have been built into each pocket to provide a bearing surface during startup and low-speed operation when hydrostatic-bearing performance is least efficient and galling and excessive wear are likely to occur.

5. Case-Manifold Subassembly

The case-manifold is designed to provide sump pickup. In operation, sodium is drawn up into the center of the pump case, passed through the impeller, and directed downward through four 6-in. volute pipes into the outlet manifold. Discharge from the manifold is provided by a section of 12-in. pipe connected to the primary-system piping by a ball-seat arrangement. This arrangement allows easy removal of the pump assembly from the primary tank by vertical lifting. The lower end of the discharge pipe has a set of bellows and springs that force the ball downward into a matching seat, which is part of the lower sodium piping. Figure 4 illustrates the ball-joint connector. When the pump is mounted, the seating force is approximately 6000 lb and an effective seal is maintained.

III. OPERATION OF MAIN PRIMARY-SODIUM PUMPS

The two main primary-sodium pumps have been in operation at EBR-II since April 16, 1963. Some difficulties experienced during this period are briefly related here.

A. Initial Operating History

Initial testing of the primary system included low-speed operation of each pump and showed incipient failure in both units. Binding occurred in pump No. 1 on April 23, 1963, shortly after startup. Pump No. 2 failed similarly on August 18, 1963, after 188 hr of operation.

Equipment was designed and procedures were developed for removal of the pumps from the primary tank. Each pump was removed, cleaned, and disassembled in the reactor building.

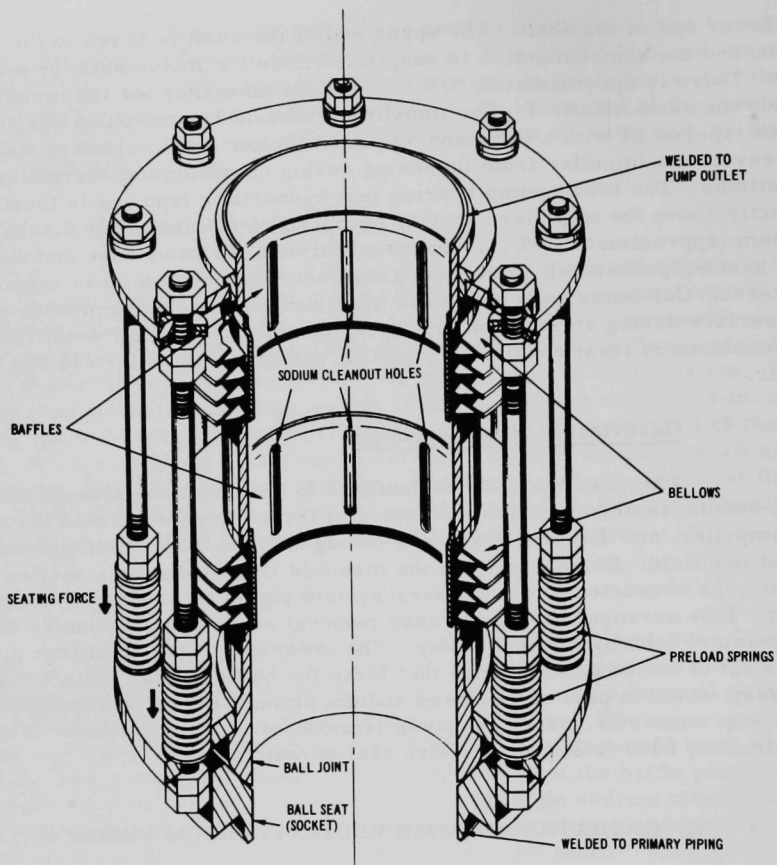


Fig. 4. Ball-joint Connector. ANL Neg. No. 103-N5417.

Inspection disclosed that in each pump the shaft and lower labyrinth were badly galled, the shaft was bowed 0.046 in., and the baffle plates were 0.075 in. off center. The shaft and lower labyrinth were therefore replaced and the baffle plates remachined to center them and increase the radial clearance. A 0.187-in. minimum clearance was provided between the shaft and the three upper baffle plates, and a 0.120-in. minimum clearance between the shaft and lower baffle plate. The lower-labyrinth clearance was increased from 0.015 to 0.124 in. The increased clearances minimized any possibility of rubbing.

Both pumps had experienced the same difficulties, were subject to the same repairs, and subsequently operated without trouble until July 1965.

B. Subsequent Operating History

Operating difficulty occurred with pump No. 1 in July 1965. After operating 4442 hr the pump appeared to have developed the same problem as previously. There appeared to be excessive rubbing between the shaft and labyrinth, causing significant rotational constraint and failure to start. To alleviate this condition, the drive motor was partially disassembled and the drawbolt loosened and tapped until the shaft assembly was lowered. The shaft was then raised and the drawbolt retightened. After approximately 200 ft-lb of torque was applied to start rotation, the breakaway torque returned to the normal value of 5 ft-lb. The same problem appeared during an attempt to start the pump five days later, and a similar procedure was again successfully used to correct the situation.

The binding was attributed to sodium and/or sodium oxide buildup in the running clearance between the shaft and labyrinth. It is assumed that sufficient sodium vapor had condensed on the shaft to cause binding. Mechanical rotation on the shaft was apparently successful in freeing the shaft and allowing normal operation. To retard the migration of sodium vapor up the shaft, the argon purge was increased from approximately 1 to 4-6 cfh on both pumps.

Both pumps operated satisfactorily for the next five years until pump No. 1 began developing the same problem again.

C. Recent Operating History

On May 18, 1970, and again on September 29, 1970, pump No. 1 underwent perturbations in power consumption without corresponding changes in primary sodium flow. The first incident occurred during a normal reactor shutdown. The console operator observed the following sequence on the console instrumentation: (a) The power consumption of pump No. 1 increased, (b) the rpm of the pump drive motor dropped to zero, and (c) the reactor scrammed. The operator then secured the power to pumps No. 1 and 2. Later analysis showed that the scram was caused by the decrease in primary sodium flow due to the decrease in rpm of pump No. 1.

On restart of the pumps, operation was normal and no further indication of binding was evident. The pumps operated in a routine manner until four months later, when a 5-kW increase in power consumption for pump No. 1 was noted during steady-state operation at 62.5 MW. Although the perturbation lasted for several minutes, the excessive power consumption continuously decreased until it returned to normal.

In each case, it was postulated that the buildup of sodium or sodium oxide on the pump shaft had caused rubbing at the lower labyrinth. As rubbing occurred, the pump power consumption automatically increased in

an attempt to maintain constant pump speed. The binding ceased when sufficient sodium or sodium oxide buildup was reduced by the argon purge or was rubbed off to establish a small clearance between the labyrinth and pump shaft.

The decision was made to remove the pump during the next scheduled maintenance shutdown. Following plant shutdown on November 15, 1970, the pumps were secured and preparations made for removal of pump No. 1.

IV. REMOVAL OF PRIMARY SODIUM PUMP NO. 1

The removal of primary sodium pump No. 1 was a complex operation. Only the main highlights are covered by this report.

A. Pump-removal Procedure

The removal of a component from the primary sodium system requires specialized equipment, procedures, and safety measures. It is essential that the integrity of the primary tank and its supporting systems remain intact. A large component must be removed in a closed system with an inert atmosphere common to that maintained over the bulk sodium. The argon-cover-gas pressure in the primary tank must remain positive during removal procedures in order to minimize inleakage of air. Nitrogen, hydrogen, and oxygen are continuously monitored on the primary-gas chromatograph to ensure that acceptable impurity levels are being maintained.

1. Equipment

As shown in Fig. 5, the pump-removal assembly consists of three major components: a spool piece (adapter section), a silo (caisson), and a silo piston. To remove a pump, the spool piece and silo are positioned over the pump and the pump is lifted into the silo in an inert-gas atmosphere.

The silo is a large cylindrical caisson, 30 ft long and 78 in. in diameter. It is open and has bolting flanges on each end. Viewing windows and gas connections are provided around the circumference at the lower end of the silo.

The spool piece is a rectangular adapter section that serves as the connector between the silo and the pump nozzle. As in the silo, viewing windows and gas-line connections are located in the sides of the spool piece. After the pump-drive motor and gas-seal membrane are removed, the spool piece is set in an I-beam support structure over the pump nozzle and sealed to the nozzle skirt by a sheet-metal enclosure. The spool piece contains a trapdoor that seals the primary tank once the pump is raised into the silo. After the spool piece is in place, the silo is positioned over, and bolted to, the top of the spool piece.

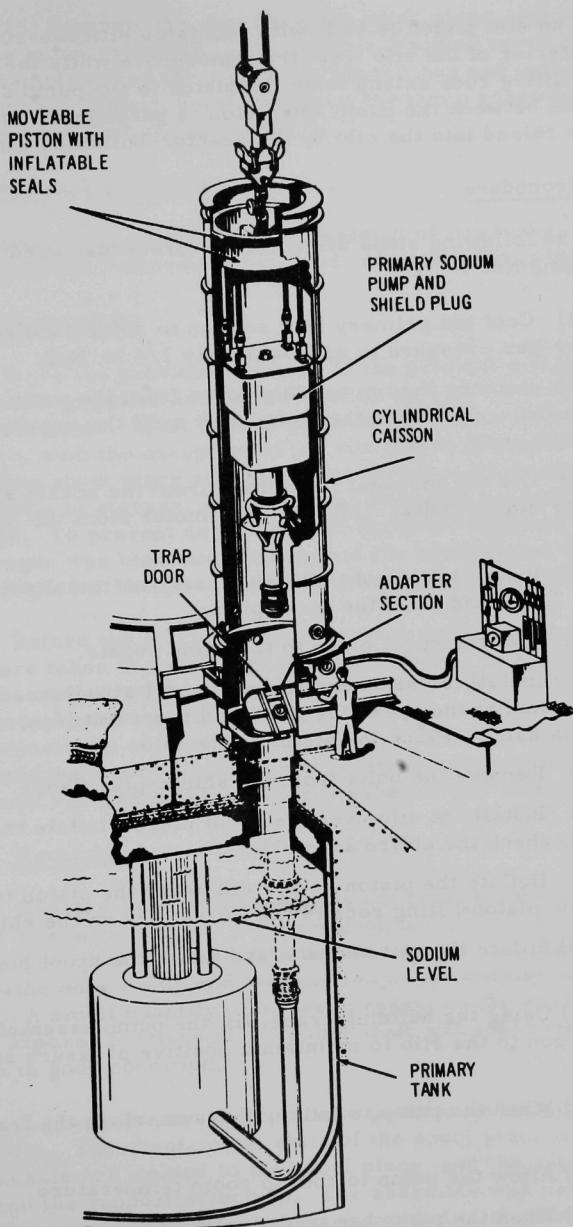


Fig. 5. Pump-removal Assembly. ANL Neg. No. 103-N5101.

The silo piston is built with inflatable silicone-rubber seals to isolate the interior of the silo from the atmosphere while the pump is being lifted. Four lifting rods extend from the piston to the pump shield plug. Once the space between the pump and piston is purged with argon, the piston and pump are raised into the silo by the reactor-building crane.

2. Procedure

The following steps are the basic procedure used in the removal of primary pump No. 1:

(1) Cool the primary bulk sodium to 300°F, and reduce the primary-cover-gas pressure to approximately 1/4 in. H₂O.

(2) Remove the top bearing cover from the pump drive motor, loosen the drawbolt, and lower the pump shaft until the impeller rests on the bottom of the pump case.

(3) Cut the gas-seal membrane from the nozzle skirt, and remove the motor-flange bolts. Lift the pump motor from the pump shield plug.

(4) Install the spool piece and the sheet-metal skirt over the pump nozzle. Level and align the spool piece.

(5) Seal the spool piece to the pump nozzle.

(6) Install the silo- and pump-support structures in the reactor-building north hatch at the operating floor and basement levels. Place the silo in the north hatch. Place the piston in the silo.

(7) Remove the bolts from the shield-plug flange.

(8) Install the silo over the spool piece. Inflate the piston seals, and leak-check the entire assembly.

(9) Deflate the piston seals, and lower the piston to the shield plug. Attach the piston lifting rods to the lifting lugs on the shield plug.

(10) Inflate the piston seals, and purge the spool piece and the silo with argon.

(11) Using the building crane, lift the pump assembly into the silo. Supply argon to the silo to maintain a positive pressure as the piston is raised.

(12) When the pump is fully withdrawn, close the trapdoor in the spool piece.

(13) Allow the pump to cool to room temperature.

(14) When the pump has cooled, slowly add instrument air to the silo to oxidize the sodium adhering to the pump assembly at a controlled rate.

(15) Separate the silo from the spool piece, and move the silo containing the pump assembly to the reactor-building north hatch. Lower the pump assembly out of the silo into a plastic bag and onto the pump-support structure. Detach the piston from the pump assembly, and remove the silo and piston from the north hatch.

B. Pump-removal Operations

The pump-removal operation consisted of two tasks: first, preparing for the pump removal; and second, removing the pump.

1. Preparation

Since the previous removal of the primary sodium pumps, the pump-removal equipment had been stored in an outside area and exposed to the natural elements. Most of the equipment had been painted before storage and therefore, with the exception of the silo piston, remained in excellent condition. The spool piece and silo cover plates were used to cap the ends of the silo while in storage, and the lifting rods and associated gear were placed inside. To prevent degradation of material surfaces during this period, nitrogen was bled into the silo and the atmosphere thereby kept inert. The silo piston, because of inadequate storage, sustained some oxidation.

Before the start of pump-removal work, pump-shaft torque readings were taken in an attempt to determine the rotational restriction, if any, due to sodium oxide deposits on the shaft. Initial shaft breakaway required an applied torque of 80 ft-lb. The pump shaft was lowered and raised by adjustment of the drawbolt, which resulted in freer movement of the shaft, independent of elevation and rotational direction. The torques required were reduced to 29 ft-lb for breakaway and 10 ft-lb while rotating.

2. Removal

The gas-seal membrane was cut from the nozzle skirt, and the shield plug was inspected for contamination and argon leakage. Neither was found. The motor-flange bolts were removed, and the drive motor was lifted from the shield plug and transferred to the sodium boiler building for inspection. A small quantity of oil was present on the surface of the shield plug. The exposed portions of the pump shaft and upper labyrinth were found to be in good condition.

I-beams were set in place to position and support the spool piece and silo. The sheet-metal skirt of the spool piece was prefitted to the pump nozzle and welded to the spool piece, and the entire assembly was lowered onto the support structure. The assembly was next leveled and aligned. The spool-piece skirt was tack-welded to the nozzle skirt, and a silicone-rubber sealant was applied to prevent argon leakage during pump removal.

The interior of the silo was coated with silicone grease to allow free movement of the piston and to ensure a seal.

Eight of the studs to which the shield plug is normally bolted were removed from the primary-pump nozzle and replaced by 12-in.-long guide pins. The pins were used to align the shield plug with the nozzle. The skirt walls and the upper surface of the shield plug were marked to ensure proper alignment during reinstallation.

A mirror was placed on top of the piston so that dynamometer readings could be taken from the crane above. (When the pump was reinstalled into the primary tank, this mirror was replaced by a closed-circuit TV system.)

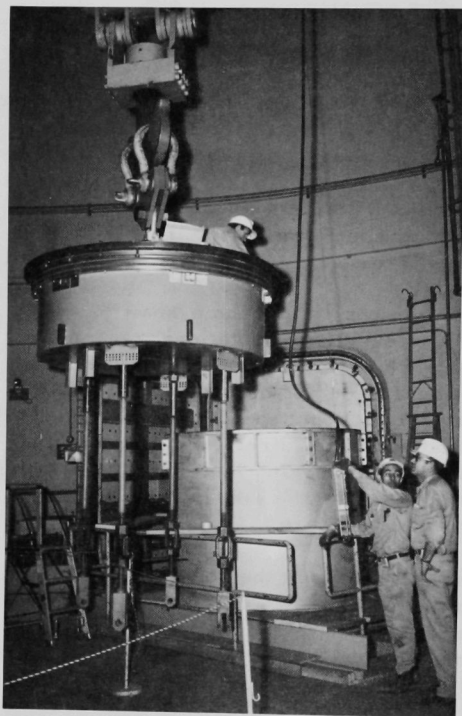


Fig. 6. Primary-pump Removal Equipment.
ANL Neg. No. 103-N5828.

To check on the integrity of all members exposed to loading, a comprehensive load test was conducted just before the actual pump removal. It was decided that the most appropriate method of testing the equipment from the piston down would be to test it in place over the pump.

Two piston lifting-rod assemblies (rods, pads, nuts, turnbuckles, etc.) were tested at a time, with the dynamometer used as a load gauge. A 27,000-lb load was applied to each set of rods, representing 125% of the anticipated pump mass to be lifted by each set. Figure 6 shows the silo piston with four attached lifting rods. Following the test, all equipment was disassembled and inspected. No deformation was found.

The crane lifting fixture, shackles, and dynamometer were disassembled and taken to NRTS

Central Facilities for load testing. The entire apparatus was subjected to 42,000 lb for 5 min, 55,000 lb for 5 min, and 82,000 lb for 5 min. Once again, no visible deformation occurred.

All lifting equipment was then visually inspected at 10X magnification and dye-penetrant inspected. These inspections also involved all piston welds subject to stress from lifting. All equipment was found to be in satisfactory condition, except for two small cracks in a piston weld and corrosion on the eight lifting-rod nuts. New high-tensile nuts were ordered, and the piston-weld cracks were repaired and reinspected to ensure structural integrity. After the load testing was complete, the silo piston was fixed to the silo and the silo mated to the spool piece. Figure 7 shows the pump-removal equipment in position over the pump nozzle.

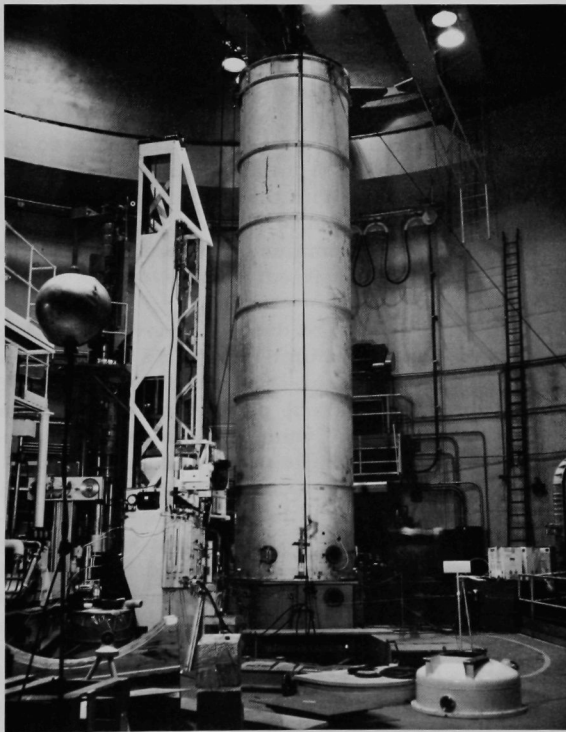


Fig. 7. Pump-removal Equipment in Position.
ANL Neg. No. 103-O5590.

Actual removal of the pump assembly from the primary tank began on December 27, 1970. The manhole cover was removed from the spool piece, and the lifting rods were connected to the lifting pads. The lifting-rod turnbuckles were adjusted to identical lengths so that the pump load would be evenly distributed. A partial load of 10,000 lb was applied, then removed, and the rods checked and readjusted. This procedure was

repeated for 20,000 lb and finally for the full load (41,000 lb), at which point the pump was raised approximately 1/8 in. from its seat.

With the piston seals deflated, the skirt, spool piece, and lower silo (below the piston) were purged with argon at 7 cfm. Purging continued until the oxygen analyzer indicated an oxygen content of 200 ppm. With the purge completed, the piston seals were inflated to approximately 3 psig and were maintained at this pressure throughout the entire pump removal. The silo was pressurized to approximately 1/4 in. H₂O.

During removal operations, a radiation monitor was placed at the wall of the spool piece just below the base of the silo. The highest activity level recorded at this location was 45 mR/hr. This occurred when the hydrostatic bearing was adjacent to the monitor.

A temperature monitor was similarly located on the spool-piece wall. Readings increased from approximately 84°F during early stages of removal to 92-95°F. With the pump almost clear of the primary nozzle, the temperature increased to approximately 100°F. The primary-tank blanket-gas temperature remained constant at about 225°F during removal.

The initial crane speed during removal of the pump was 2 in./min. This speed was maintained until the shield plug was well past the pump nozzle. Argon makeup to the silo assembly during withdrawal was approximately 3½ cfm. This makeup covered the combined effects of argon leakage past the piston seals and volume increase due to piston movement. With the piston stationary in the silo, argon makeup (piston-seal leakage) was approximately 30 cfm.

Once the pump was withdrawn about 130 in., the crane was switched to high speed (10 ft/min). It was found, however, that only short periods of vertical movement could be maintained and still keep the silo at a positive pressure.

The dynamometer reading with the crane operating at low speed was 41,000 lb. Momentary dynamometer readings associated with the high-speed crane operation were 43,500 lb.

Once the pump was completely drawn into the silo and the trap-door closed, the piston was bolted to the silo and the pump allowed to cool. During the first 24 hr of this cooling period, the seals remained inflated and the silo pressurized. This was followed by an 8- to 10-hr period of bleeding instrument air into the silo with the seals deflated. This process caused the sodium on the pump assembly to oxidize. The oxide coating reduced the danger of fire while the unit was being transferred to the cleanup and disassembly area.

After the pump had been sufficiently cooled and the surface sodium oxidized, the pump, piston, and silo were placed over the north hatch. The pump assembly was lowered out of the silo into a polyethylene bag and supported by the shield plug and baffle flanges on a structure installed in the hatch at the basement level. The silo and lifting apparatus were removed from the hatch and stored on the operating floor for pump reinstallation. The pump was ready for disassembly.

V. DISASSEMBLY OF PRIMARY SODIUM PUMP NO. 1

The pump was disassembled and examined in the reactor building. The sodium cleaning and radioactive decontamination were then performed mainly outside on the sodium cleanup pad. Highlights of this work are given in the following subsections. Further details of the disassembly work are given in Appendix B.

A. Pump-disassembly Procedure

This task included two basic subtasks: preparing and installing the required equipment, and developing the disassembly procedures to be used.

1. Equipment

The pump-support structure used for disassembly had been fabricated for the previous pump removal in 1963. This structure consisted of two parallel 18-in. I-beams connected laterally with two 8-in. channels. The structure bridged the north hatch opening in the reactor-building basement floor. After removal of the 34,000-lb shield plug from the pump assembly, two 4-in. I-beams were placed laterally across the 18-in. I-beams and through two opposite openings in the pump's volute piping to support the remaining pump assembly.

Special skids were designed and fabricated for the case-manifold and shaft-impeller subassemblies for transferring them from the reactor building to the outside sodium-cleanup pad. Cleaning tanks were designed and fabricated for the baffle, the bellows, the impeller, and the complete case-manifold subassembly (all to be used on the sodium-cleanup pad).

Slings, sodium oxide containers, fire-retardant anticontamination protective clothing, radiation-monitoring equipment, scaffolding, etc., were obtained and identified for the pump-disassembly work as required.

2. Procedure

The pump-disassembly procedure consisted of the following basic steps:

(1) Survey the pump assembly for radiation to establish working requirements.

(2) Establish radiation-safety and contamination-control procedures.

(3) Install an argon atmosphere for the case-manifold, including discharge piping and bellows.

(4) Remove the pressure transmitter from the pump, clean, and inspect.

(5) Remove the upper labyrinth, clean, and inspect.

(6) Scrape the sodium oxide from the pump assembly, place the oxide in containers, label as to location, and send to the chemistry laboratory for analysis. (This same procedure was followed for the entire pump disassembly.)

(7) Separate the shield plug from the pump assembly and place it in a contamination-controlled area on the operating floor for cleaning. Clean and inspect the assembly bolts.

(8) Examine the sodium oxide buildup on the pump shaft for evidence of rubbing and binding.

(9) Lift the remainder of the pump assembly to the operating floor, perform extensive gamma-scan and radiation survey, and set the pump back on the support structure.

(10) Remove the lower labyrinth, clean, and inspect. (Note: This step could not be accomplished as planned because the bolts could not be removed to free the labyrinth owing to its corroded condition.)

(11) Separate the flanges of the baffle and case-manifold, remove the baffle, and wrap it in polyethylene. (Note: The baffle was raised up over the pump shaft with the lower labyrinth still installed.)

(12) Gamma-scan and radiation-survey the baffle, and transfer it to the sodium-cleanup pad.

(13) Remove the shaft-impeller from the case-manifold and wrap it in polyethylene.

(14) Gamma-scan and radiation-survey the shaft-impeller, and place it in a contamination-controlled area on the operating floor for shaft cleaning and partial impeller cleaning.

(15) Lift the case-manifold clear of the support structure, wrap it in polyethylene, and remove it to the operating floor with the argon supply remaining connected to the bag enclosing the bellows.

(16) Gamma-scan and radiation-survey the case-manifold; then place it on its special handling skid and transfer it to the sodium-cleanup pad. Connect an argon supply cylinder to the bellows bag in place of the reactor-building argon supply.

(17) Clean the top and side surfaces of the shield plug; then lift the shield plug and clean the bottom surface and liner until the radioactive contamination has been reduced to safe levels.

(18) Clean and decontaminate the baffle, impeller, and case-manifold subassemblies by submerging and soaking in ethyl alcohol followed by hot-water rinsing. Repeat the submerging and soaking (with scrubbing) in a decon solution for radioactivity decontamination, followed by a hot-water rinse.

(19) Submerge the baffle, shaft-impeller, and case-manifold subassemblies in ethyl alcohol to eliminate water pockets. Drain and wrap the subassemblies in polyethylene, and transfer them back to the reactor building for inspection.

(20) Examine the pump components throughout disassembly and cleaning work to note the condition. Take photographs showing all phases of the work and conditions of the pump components.

B. Pump-disassembly Operations

The pump disassembly and cleaning were complicated by the level of radioactivity (400 mR/hr at 1 in., maximum) revealed when the pump was surveyed. The considerable amount of adherent sodium and sodium oxide created a fire hazard as well as a radiation hazard. Special precautions were required to limit the radiation exposure of personnel, to limit the spread of contamination, and to prevent sodium fires.

1. Preparations

After the pump assembly had been set on the support structure at the basement level of the north hatch, the radiation survey was made. The radiation levels indicated that the pump assembly should be enclosed in a contamination-controlled enclosure. A wood and polyethylene structure was constructed starting at the subbasement floor, extending through the basement hatch and up to about 4 ft above the top of the pump, with change rooms at the subbasement and basement levels for controlled entry and exit to the enclosure. A removable plywood-polyethylene top cover was

installed over the enclosure with a center opening for the building-crane hoisting cable and building air intake. An absolute-filtered exhaust unit was installed in the subbasement at the floor level to provide air circulation down through the enclosure. Removable scaffolding was installed in the basement hatch opening and in the subbasement.

The protective clothing required was full fire-retardant, anti-contamination clothing with full face shields and supplied air. Continuous monitoring was established over radiation levels, air supply, fire hazard, and disassembly work. All other preparations had been previously completed.

The pump was set in position for disassembly on December 29, 1970 (see Fig. 8). The following day an inflatable seal was installed inside the case-manifold discharge pipe above the bellows, and a separate polyethylene bag was installed over the bellows. The air was purged from the bag and from the bellows assembly both internally and externally, and an



Fig. 8. Pump Positioned for Disassembly. ANL Neg. No. 103-O5041A.

argon atmosphere was established at a set leak rate of 10-15 cfh. The argon was supplied from the reactor-building supply. This extra precaution was taken because the inside of the bellows is inaccessible for visual inspection and cleaning, owing to the internal baffles. Keeping an argon atmosphere on the bellows minimized the possibility of damage from a sodium-air reaction. The argon atmosphere was maintained until the bellows was immersed in ethyl alcohol for cleaning.

2. Disassembly

Pump disassembly began on January 4, 1971, with removal of the pressure transmitter. The 1/2-in. connecting pipe welded to the 12-in. discharge pipe was ground off. The capillary-tube support clips were ground off using a special tool to prevent damaging the NaK-filled tube.

The shield plug was manually scraped to remove the adherent sodium and sodium oxide. The assembly bolts fastening the shield plug to the baffle were removed. Considerable difficulty was encountered in gaining access to the bolts to grind off the tack welds. The pump assembly had to be repositioned several times by rotating it relative to the support structure.

As expected, the upper labyrinth was removed without difficulty since it had previously been removed before the pump removal for an upper-pump-shaft inspection.

The shield plug was lifted off the pump assembly, wrapped in polyethylene, and set on the operating floor in a contamination-controlled area for cleaning.

The length of pump shaft exposed by the shield/plug removal was examined. The rub marks on the shaft, the sodium oxide buildup, the corroded condition of the lower labyrinth, and the grease-trail patterns on the shaft were noted.

The pump assembly (less shield plug) was lifted to the operating floor and extensively gamma-scanned and radiation-surveyed to determine the disposition of specific isotopes. It was then lowered back into the hatch onto the support structure.

An attempt was made to remove the badly corroded lower-labyrinth assembly bolts; however, they could not be removed by wrench. Owing to the limited access, an air-operated angle drill was used to try to drill out the bolts (1/2-in. socket head). The drilling was proceeding very slowly (5 min would dull the drill bits) when it was noted that the hard sodium oxide buildup on the pump shaft above the seal had softened because of moisture absorption from the air. The bolt drilling was stopped, the pump shaft was scraped free of sodium oxide, and the baffle removal proceeded with the lower labyrinth installed.

The baffle would not lift off the case-manifold after the assembly bolts were removed. The bottom end of the baffle that extends inside the case-manifold was bound with solid sodium. Jacking screws were installed in the tapped holes provided in the lower flange of the baffle, and the removal of the baffle was begun by lifting with the building crane while tightening the jacking screws. The approximately 1-ft-long bottom end of the baffle that was inserted inside the case-manifold with a close fit had to shear and extrude through the sodium as it was withdrawn. Approximately 2500 lb of lift was applied, and then the jacking screws were tightened as far as possible. This lowered the dynamometer reading to approximately 1500 lb and raised the baffle approximately $1/16$ in. This procedure had to be repeated for over 8 hr before the baffle was withdrawn from the case-manifold. Asbestos blankets had to be wrapped loosely around the flange area, and an argon supply at 15 cfh was installed inside to retard the sodium oxidation. The baffle was removed, wrapped in polyethylene, and lifted to the operating floor.

During removal of the baffle, a small sodium fire started inside the baffle. The two technicians working inside the enclosure quickly inserted an argon supply line inside the baffle through one of the drain holes and taped the other drain holes closed. This put out the fire before any damage or release of contamination occurred.

The baffle was gamma-scanned and radiation-surveyed, and then transferred to the sodium-cleanup pad.

The shaft-impeller was lifted out of the case-manifold with some difficulty. It, too, was bound inside the case-manifold with solid sodium. The entire unit was lifted by the pump shaft until it lifted $1/16$ - $1/8$ in. off the support structure. The weight of the case-manifold then caused it to slowly settle back to the support structure. This was repeated for approximately 2 in. before the shaft-impeller lifted free. It was then wrapped in polyethylene and lifted to the operating floor.

The shaft-impeller was gamma-scanned and radiation-surveyed and then set in support saddles in a contamination-controlled area for preliminary cleaning. After this operation, the shaft-impeller was rewrapped, placed on its special skid, and transferred to the sodium-cleanup pad for completion of the impeller cleaning.

The case-manifold was lifted free of the structural supports without difficulty, wrapped in polyethylene, and lifted to the operating floor, where it was gamma-scanned and radiation-surveyed. It was then placed on its special handling skid with an argon-supply cylinder attached to the bellows bag, and transferred to the sodium-cleanup pad.

The baffle was lifted by yard crane to the roof of the Fuels and Examination Facility and moved into the decontamination cell for a decontamination-spray wash. This decontamination process failed to lower the

contamination level of the baffle. It was then moved into the decontamination shop, and the lower-labyrinth bolts were drilled out with a power drill. The threaded portions of the bolts were removed with an easy-out. The salvageable portion of the bolts and the labyrinth were cleaned and inspected. The baffle was then transferred back to the sodium-cleanup pad for decontamination by submersion soaking.

3. Examination during Disassembly

The examination of the pump as it was disassembled revealed the following items:

(1) Radiation was higher than anticipated. Table II tabulates representative values before and after decontamination.

(2) Rubbing had occurred between the shaft and the sodium oxide buildup on the shield-plug liner.

(3) Considerable corrosion of the lower labyrinth had destroyed its usefulness (see Fig. 9).

(4) Heavy sodium oxide deposits were on the pump shaft on the 9.500-in. diameter above the slinger grooves (see Fig. 10).

(5) There was a large quantity of sodium and sodium oxide inside the baffle. The area between the upper baffle plate and top flange was nearly filled (see Fig. 11).

(6) Grease from the lower bearing of the drive motor had leaked into the end bore of the pump shaft, out the keyway relief holes, and down the shaft (see Fig. 10).

(7) The grease-retention assembly for the lower bearing of the drive motor had failed to completely retain the grease (see Fig. 12).

(8) The sump area of the case-manifold was relatively free of sodium and sodium oxide (see Fig. 13).

(9) The pump, in general, was in good condition (except for the lower labyrinth) after over 32,000 hr of operation over a period of eight years in a radioactive sodium environment under varying conditions of load, flow, and temperature.

(10) The lack of galling of the stainless steel assembly bolts tapped into stainless steel flanges demonstrated that the process of nitride hardening of the threads to prevent galling was successful.

TABLE II. Data on Decontamination of Components of Primary Sodium Pump No. 1

Major Subassembly	Maximum Size	Approx Weight, lb	Cleaning Tank		Radiation Levels, ^a R/hr and dpm/100 cm ²	
			Size	Capacity, gal	Before Decontamination (max)	After Decontamination (max)
Shield plug	4 ft 5 in. x 6 ft 1 in. x 6 ft 7 in.	34,000	None	-	1 R at 2 in. $\alpha = 100$ $\beta\gamma = 7.0 \times 10^5$	50 mR at 1 in. $\alpha = 10$ $\beta\gamma = 4.2 \times 10^4$
Baffle	33-in. OD x 4 ft 5 in. long	2,000	48-in. ID x 6 ft deep	1,950	400 mR at 2 in. $\alpha = 9800$ $\beta\gamma = 1.2 \times 10^6$	90 mR at 1 in. $\alpha = 270$ $\beta\gamma = 7.4 \times 10^3$
Shaft-Impeller ^b	26-in. OD x 11 ft 9 in. long	2,500	28-in. ID x 3 ft 6 in. deep	600	550 mR at 2 in. $\alpha = 2000$ $\beta\gamma = 2.9 \times 10^6$	100 mR at 2 in. $\alpha = 10$ $\beta\gamma = 1.6 \times 10^3$
Case-Manifold ^c	48-in. OD x 10 ft 9 in. long	2,000	4 ft x 12 ft x 4 ft deep	14,000	475 mR at 2 in. $\alpha = 2000$ $\beta\gamma = 2.0 \times 10^5$	160 mR at 1 in. $\alpha = 40$ $\beta\gamma = 4.0 \times 10^4$
Drive motor	46-in. OD x 6 ft long	10,000	None	-	-	-
Cooling blower	2 ft 3 in. x 2 ft 7 in. x 2 ft 3 in.	350	None	-	-	-

^aThe source of alpha radiation was ²¹⁰Po. The source of the ²¹⁰Po was ²⁰⁹Bi. Bismuth entered the primary sodium on or before July 1965, probably from the seals of one or both rotating plugs.

^bOnly the impeller was cleaned in the cleaning tank. The shaft was hand-cleaned in the reactor building.

^cThe bellows assembly on the end of the 12-in. discharge pipe was initially cleaned in the 600-gal tank. Later the entire case-manifold was cleaned (bellows assembly recleaned) in the 14,000-gal tank. The inside of the bellows assembly was not accessible for radiation surveying before cleaning because of the argon purge established on it. The radiation levels inside the bellows assembly after decontamination were as follows: 200 mR/hr at 5 in., $\alpha = \text{dpm}/100 \text{ cm}^2$, and $\beta\gamma = 6.6 \times 10^3 \text{ dpm}/100 \text{ cm}^2$.

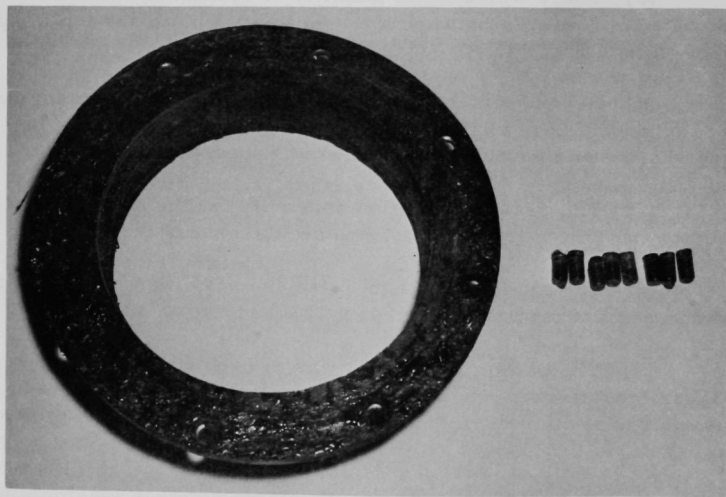


Fig. 9. Removed Lower Labyrinth. ANL Neg. No. 103-O5364.



Fig. 10. Sodium Oxide on Pump Shaft. ANL Neg. No. 103-O5099.



Fig. 11. Sodium Oxide in Baffle. ANL Neg. No. 103-O5194A.

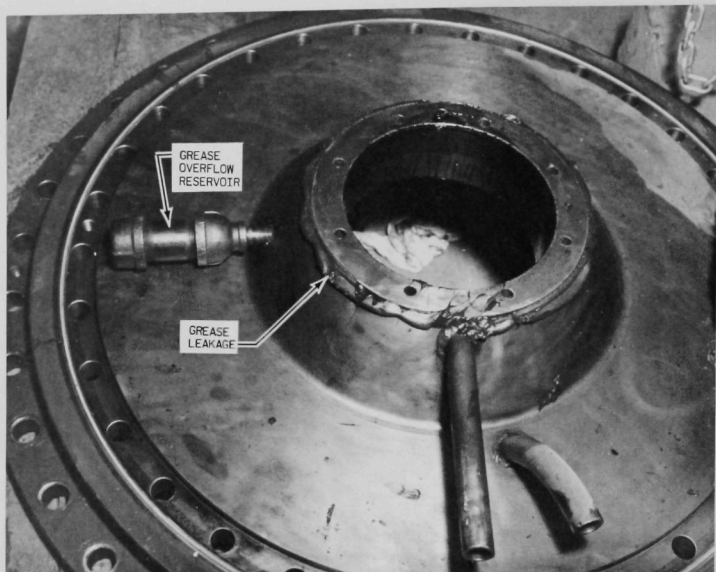


Fig. 12. Seal for Lower Bearing of Drive Motor. ANL Neg. No. 103-O5063A.



Fig. 13. Interior of Case-Manifold. ANL Neg. No. 103-O5173.

4. Sodium Cleaning

Cleaning of sodium from all pump subassemblies (except the shield plug) was performed on the large sodium-cleanup pad. This is an open metal-covered concrete pad isolated from the EBR-II facility buildings for safety. Use of this pad was complicated by the adverse winter weather (see Fig. 14).



Fig. 14. Large Sodium-cleanup Pad in Use during Adverse Winter Weather. ANL Neg. No. 103-O5188.

Sodium cleaning of the pump subassemblies was accomplished by placing fabricated cleaning tanks on the front section of the pad and installing an argon supply line to discharge inside the tank bottoms throughout the entire cleaning process. The argon was permitted to fill the tanks, and then the pump subassemblies were placed inside the tanks by using the boom truck. The polyethylene wrapping was removed from the pump subassemblies as they were lowered into the tanks. Vented metal tank covers were then placed on the tanks and the tanks were filled remotely with ethyl alcohol through the drains. The alcohol was gradually diluted to a 50-50 alcohol-water mixture during the soaking until all sodium reaction had ceased. The diluted alcohol was then drained out of the tanks and the pump subassemblies were hot-water-washed in the tanks, lifted out and covered with polyethylene, and held for decontamination (see Fig. 15).

5. Radioactivity Decontamination

Partial decontamination of the pump subassemblies was accomplished by soaking them in the tanks that were used for sodium cleaning. The tanks were washed, an argon supply was installed in the tanks, a Turco No. 4521 decon solution was mixed in the tanks, and the pump subassemblies were submerged in the decon solution (see Fig. 16). An agitator was installed in the tank for the case-manifold to provide adequate circulation.



Fig. 15. Sodium Cleaning. ANL Neg. No. 103-O5220.



Fig. 16. Radioactivity Decontamination of Case-Manifold.
ANL Neg. No. 103-O5543.

The decon solution was mixed according to the manufacturer's direction, and the soak was performed for 4 hr at a decon-solution temperature of 150°F. The subassemblies were scrubbed with long-handled fiber brushes and mops during the soaking period. Argon was bubbled through the decon solution to keep it agitated.

Reference 5 gives additional information on the cleaning and decontamination of the pump.

VI. INSPECTION AND REPAIR OF PRIMARY SODIUM PUMP NO. 1

The pump drive motor, the upper and lower labyrinths, and the shield-plug, baffle, shaft-impeller, and case-manifold subassemblies were inspected to determine their condition and to compare dimensions with those measured in 1963. All pump assembly bolts were inspected for thread profile, dimensions, and evidence of bolt stretch.

A. Replacement of Pump Components

The following pump components were replaced with new spares because of component failure or to expedite the reassembly work.

1. Lower Bearing and Seal of Drive Motor

The drive-motor inspection revealed considerable wear in the lower roller bearing. The inspection also revealed that the felt seal had become hardened from excessive grease absorption. The bearing life (according to the manufacturer) is between 30,000 and 40,000 hr of operation. Since the bearing had operated over 32,000 hr and probably could have run several thousand hours more, it was considered to have performed satisfactorily.

2. Lower Labyrinth

The lower labyrinth was severely corroded on its top surface, flange edge, and inside-diameter serrations (see Fig. 9). A new labyrinth of improved design was installed.

3. Assembly Bolts

All pump assembly bolts were replaced with new bolts to expedite the reassembly work.

4. Pressure Transmitter

The pressure transmitter appeared satisfactory; however, this was the second time it had been removed. Since the diaphragm between the

NaK-filled capillary tube and the primary sodium could not be inspected, the decision was made to replace the transmitter with a new unit and hold the removed unit as an emergency spare.

B. Inspection

Critical dimensions and welds were inspected to determine if any problems existed and to obtain dimensions for comparison with past inspection records and future inspections.

1. General

The critical pump-assembly dimensions were within the manufacturer's drawing tolerances. The lower labyrinth could not be dimensionally checked because the corrosion was too severe to permit measuring. The pump-assembly bolts had been stretched through the threaded portion that did not engage the threads in the tapped holes, making them unsatisfactory for reuse. The bolts were sent to the analytical-chemistry and metallurgical laboratories to be used as specimens for analysis.

The weld inspections were made with a 3X and 10X magnifying glass. Extensive inspections were made on the welded bellows segments and the welds of the four 6-in. volute pipes to the 12-in. discharge pipe. No weld flaws were detected.

Visual inspection showed all pump components not specifically discussed above to be in as-new condition. The components in this category included the hydrostatic bearing, bearing sleeve (journal), impeller, discharge static seal (ball joint), assembly mechanical connections, welds, sodium-flow surfaces, and upper labyrinth. No evidence of rubbing, wear, cavitation, corrosion, or damage was found.

2. Comparison

A comparison of the measured dimensions with those made in 1963 disclosed that they were nearly identical. This indicated no measurable loss of material from the pump subassemblies since the last inspection. It also indicated that the strength and stability of the pump is satisfactory, since no bowing, warpage, shrinkage, elongation, etc., had occurred. There was approximately a 0.004-in. loss of diameter on the 9.500-in.-dia pump shaft where the sodium oxide ground out the serrations on the aluminum-bronze lower-labyrinth seal. This difference is considered insignificant, however, since limits of accuracy of measurement could account for most of this difference.

3. Gamma Scan

The gamma scan and radiation survey of the pump assembly after the shield plug was removed has been reported in Ref. 4. A report⁵

is being written to cover the data obtained from all gamma scans and radiation surveys plus the material analyses of samples taken during the pump removal and repair work. The data obtained from the initial gamma scan and radiation survey⁴ are of particular interest, since the survey was made of the assembled pump (less shield plug) in the "as-removed" condition. The adhering sodium and sodium oxide were virtually intact on and in the pump at this time.

The gamma scan was made with a Ge(Li) gamma detector 44 in. from the pump centerline. A Juno survey meter 1 ft from the pump surface was used to make the radiation survey. The measurements were made in the "gamma-ray only" mode on the 0- to 250-mR/hr range. The scan and radiation measurements were taken at 1-ft increments by raising and lowering the pump with the building crane. The pump was always positioned in front of the gamma detector; however, because of the pump configuration, the detector system could not be collimated to view only that segment of the pump. There was some contribution from surfaces below the line-of-sight plane normal to the pump axis.

Figure 17 shows the pump with the results of the gamma scan and radiation survey. The first plot to the right of the pump shows the radiation profile for the pump. Note that the highest reading (175 mR/hr) is just above the primary-sodium inlet to the pump and directly opposite the internal wear rings. The Stellite-hardened surface overlay on the wear rings contains cobalt, and it was originally believed that this cobalt would contribute significantly to a higher radiation level. This was apparently not the case, as shown by the plot on the right that shows the gamma profile for the strongest radionuclide activities, ^{182}Ta , ^{137}Cs , ^{60}Co , and ^{54}Mn . The ^{60}Co activity remained nearly constant at the 7-ft 6-in., 8-ft 6-in., and 9-ft 6-in. heights, whereas the radiation levels were 90, 175, and 70 mR/hr, respectively. The 175-mR/hr radiation level was evidently caused by the side effect of the two 6-in. volute pipes that the Juno survey meter was placed between.

It is believed that all the above-mentioned radionuclides were generated elsewhere in the primary system, transported by the flowing sodium, and subsequently deposited on the surfaces of the pump.

C. Modifications

Minor changes were made to the drive motor, the pump shaft, the lower labyrinth, and the baffle. These modifications were made with the concurrence of a representative of the manufacturer (Byron-Jackson).

1. Drive Motor

The only problem revealed by the drive-motor inspection was failure of the lower-bearing grease-retention system to retain all the grease.

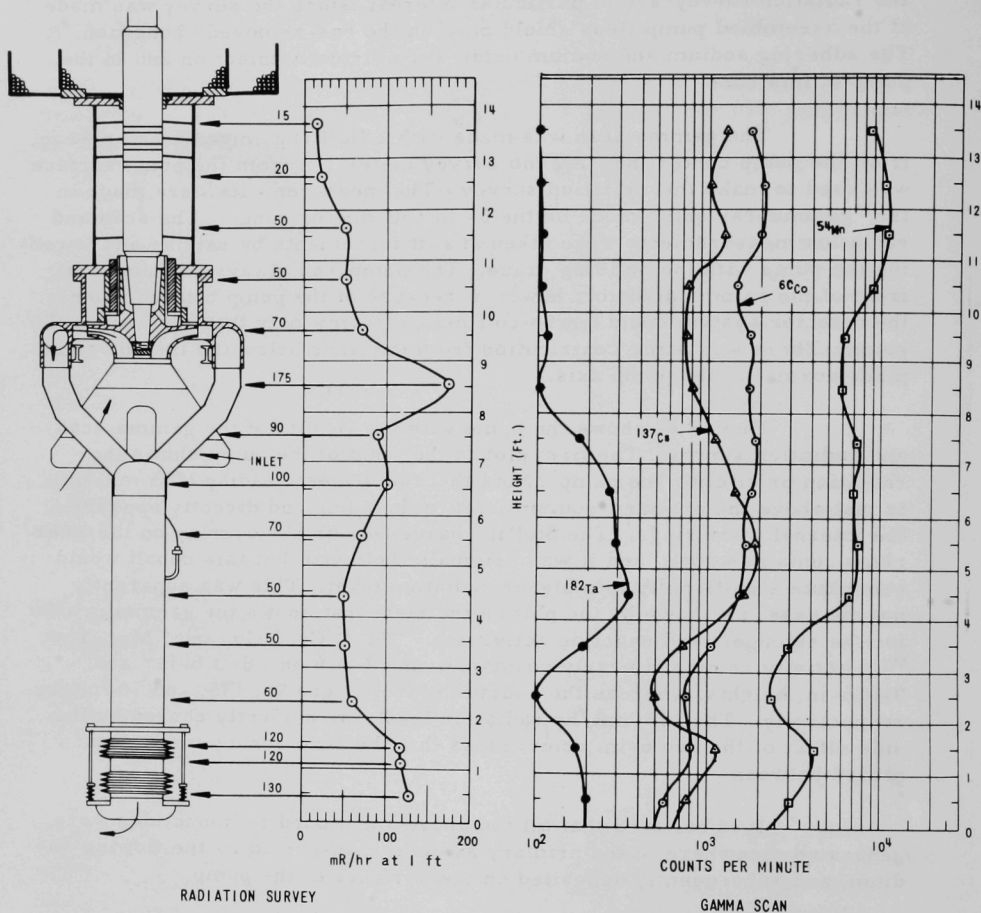


Fig. 17. Radiation Survey and Gamma Scan of Primary Pump before Cleaning and Decontamination. ANL Neg. Nos. 103-O5809 Rev. 1 and -O5810 Rev. 1.

The excess grease did not go into the small reservoir provided in the lower motor-support flange. This caused some grease to leak out and down the pump shaft. The reservoir was removed, permitting the entire space above the support flange to become a reservoir. Reliefs were machined in the assembly plate to provide easier overflow to the enlarger reservoir (see Fig. 18).

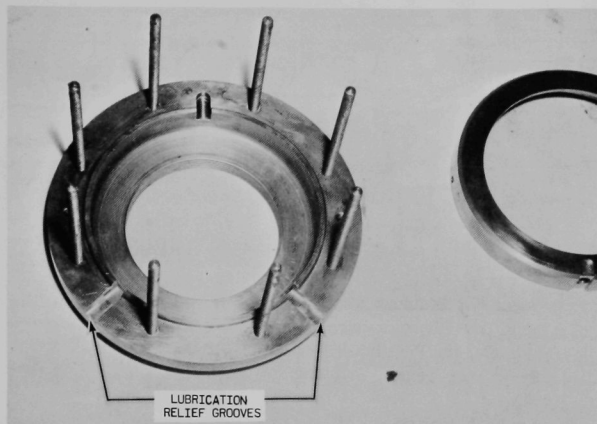


Fig. 18. Modified Grease Retainer for Lower Bearing of Drive Motor. ANL Neg. No. 103-O5603A.

The grease-application period was changed from once every 900 hr to once every 1800 hr. The type of grease was changed on this pump only, for trial use. This modification plus the new felt seal should eliminate the grease leakage.

2. Pump Shaft

The upper end of the pump shaft is bored for mating with the drive-motor shaft. This bored end has two keyways 180° apart to key to the drive-motor shaft. To machine the internal keyways in the blind bore, relief holes had to be drilled through the shaft wall at the end of the keyways. The grease that leaked from the drive-motor lower bearing ran down the motor shaft into the pump-shaft bore, out the two keyway-relief holes, and down the pump shaft.

The two keyway-relief holes were plugged (see Fig. 19) to prevent grease leakage from the pump-shaft bore, in case there is any future leakage past the grease retainer. There is a tapped hole at the bottom of the shaft bore for the drawbolt. This hole, plus the void space in the bore, provide ample reservoir capacity to hold the small amount of grease that might leak past the retainer.

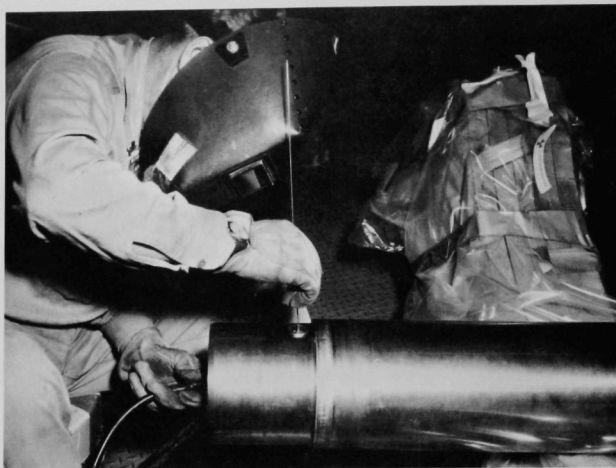


Fig. 19. Plugging of Keyway Relief Holes on Pump Shaft. ANL Neg. No. 103-O5523.

3. Lower Labyrinth

The internal serrations of the lower labyrinth were modified to improve the argon flow down between the seal and the pump shaft. The modification changed the eight-pitch, right-hand, single-lead helix to an eight-pitch, left-hand, four-lead helix. This will aid the argon flow down the pump shaft and oppose the "climbing" of sodium and sodium oxide up the counterclockwise-rotating pump shaft (see Fig. 20).

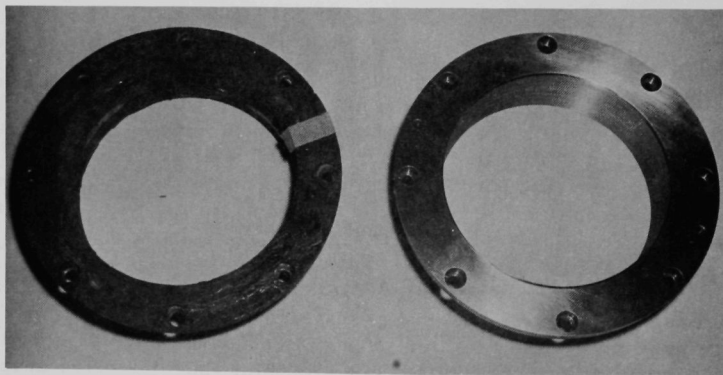


Fig. 20. New Modified Lower Labyrinth (right). ANL Neg. No. 103-O5480.

4. Baffle Subassembly

The top of the baffle is located 15.5 in. above the level of the primary sodium when the sodium is at the 700°F operating temperature. The baffle has three sets of four drain holes, one set located just above the level of each baffle plate (i.e., $6\frac{3}{8}$, $10\frac{3}{8}$, and $14\frac{3}{8}$ in. from the top of the baffle). The four holes in each set are spaced at 90° intervals and are aligned vertically with the corresponding holes in the other sets.

The sodium-slinger grooves of the pump shaft are located as follows: the first pair, between the first and second baffle plates; the second pair, between the second and third baffle plates; and the third pair, between the third baffle plate and the sodium level.



Fig. 21. Modified Baffle, with Arrows Showing New Drain Holes for Argon Purge Flow. ANL Neg. No. 103-O5557A.

The purpose of the baffle plates, drain holes, and slinger grooves was to keep sodium from climbing the rotating pump shaft by being thrown off and then draining back to the bulk sodium. The examination of pump No. 1 demonstrated that this system failed to function as planned. Sodium oxide filled the slinger grooves, plugged the baffle drain holes, filled the spaces between baffle plates with sodium oxide, filled the lower-labyrinth seal-serration grooves and shaft clearance, and built up above the lower labyrinth seal.

The baffle was modified by plugging the drain holes above the sodium level and adding new holes below the sodium level. The 12 original holes were plugged with Type 304 stainless steel pipe plugs. Three sets of two $23/32$ -in.-dia holes were drilled at 180° and located $17\frac{1}{2}$, $20\frac{1}{2}$, and $23\frac{1}{2}$ in. from the top of the baffle (see Fig. 21). All the new holes are thus located below the normal primary-sodium level at 700°F. This mod-

ification, in conjunction with the modified lower labyrinth, is expected to direct the argon purge flow down past the baffle plates into the sodium and out the new holes. It is expected that this will reduce the climbing of sodium up the shaft and the amount of sodium oxide formation on the pump shaft, lower labyrinth, and baffle plates.

VII. REASSEMBLY OF PRIMARY SODIUM PUMP NO. 1

Reassembly began on February 6, 1971. The case-manifold was first set on the basement support structure. The shaft-impeller was then set inside the case-manifold. The baffle was next lowered over the pump shaft and the lower end inserted inside the case-manifold. The mating flanges of the baffle and case-manifold were aligned by means of the alignment mark, and new assembly bolts were installed. The 1-in. bolts were torqued by 50-ft-lb increments at approximately 180° locations in sequence until 245 ft-lb of torque (30,000 psi) was applied. The bolts were then tack-welded in place.

The new lower labyrinth was placed over the pump shaft and installed in the baffle. New assembly bolts were installed. The 1/2-in. bolts were then torqued to 30 ft-lb (30,000 psi) in even increments at approximately 180° locations.

The 12 pipe plugs were removed from the baffle to unplug the original drain holes. Clearances from the pump shaft to the baffle plates and to the inside diameter of the lower labyrinth were measured through these holes. All clearances were identical to those measured in 1963. The pipe plugs were reinstalled and tack-welded in place.

The support of the partially reassembled pump was changed from the 4-in. I-beams to the 18-in. I-beams.

The shield plug was next lowered over the pump shaft onto the baffle and aligned to a previously made alignment mark. New assembly bolts were installed and sequentially torqued to 245 ft-lb (30,000 psi). The bolts were then tack-welded in place.

The upper labyrinth was reinstalled over the pump shaft in the top recess of the shield plug. New 1/2-in. bolts were torqued to 30 ft-lb (30,000 psi) in even increments of approximately 180° locations. The maximum and minimum clearances between the shaft and the inside diameter of the upper labyrinth were measured after assembly and determined to be satisfactory.

A new pressure transmitter was installed on the pump. The 1/2-in. pipe connection was welded to the 12-in. discharge pipe. The NaK-filled capillary tube was reinstalled with welded support clips.

The vertical clearance of the impeller in the case-manifold was measured by lifting and lowering it through its full travel. The clearance remained 3/4 in. as previously measured. The shaft-impeller was then suspended by a swivel connection on a chain fall to clear the impeller vertically from the case-manifold. The breakaway and turning torques were measured as 5 and 2 ft-lb, respectively.

15

The entire pump assembly was carefully examined for any evidence of damage and any potential problems. None was found. The scaffolding was cleared away from the pump, and the pump was ready for reinstallation on February 9, 1971 (see Fig. 22).

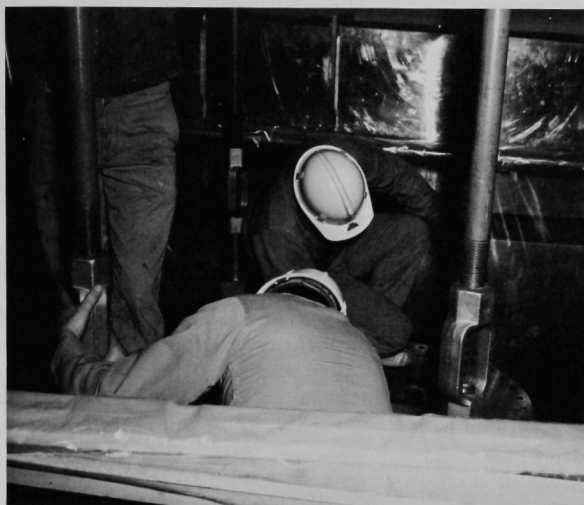


Fig. 22. Attachment of Lifting Fixture for Reinstallation of Primary Pump. ANL Neg. No. 103-O5889.

VIII. REINSTALLATION OF PRIMARY SODIUM PUMP NO. 1

Reinstallation of the primary pump was essentially a reverse of the removal procedure. After final assembly and inspection of the pump in the north hatch of the reactor building, the pump silo was placed over the hatch at the operating-floor level and the pump assembly was lifted inside. The entire unit was then set on the pump spool piece over the primary-tank nozzle. The silo was purged, the spool trapdoor opened, and the pump assembly lowered into the bulk sodium. Preheating of the pump, other than that imparted by the bulk sodium (300°F), was deemed unnecessary. At low crane speed, the thermal shock to the pump assembly was considered minimal. As the pump was lowered, it was necessary to constantly bleed argon from the silo to prevent excessive pressure increases and cycling of the primary-system floating-head tank. Some minor rotational adjustments were required to properly orient the shield plug over the guide pins. This operation was performed by use of threaded reach rods located at the lower end of the silo.

Once the pump assembly was lowered into position, the drive motor was replaced and the gas-seal membrane was welded into position. Shaft

torque readings were taken to confirm free rotational movement. The shaft rotated freely with torques of 3-5 ft-lb, which is well within accepted limits.

IX. SUBSEQUENT OPERATION OF PRIMARY SODIUM PUMP NO. 1

Following reinstallation of the pump, performance was closely monitored at several pump speeds to confirm proper operation. Data were taken at pump speeds corresponding to 37.8, 62.5, 87.3, and 100% of the maximum normal operating level (62.5 MWt). All data were in close agreement with the pump parameters recorded before removal of the pump.

The difficulties with the pump that eventually led to its removal were characterized by increased power consumption. Close attention was paid to this parameter during initial pump operation and no increased power consumption occurred. Bearing temperatures were also monitored closely, since the lower bearing had been replaced and modifications made to the lower bearing assembly. These temperatures were normal. Since the pump was reinstalled, it has undergone over 1500 hr of operation with no abnormalities.

X. SUMMARY

Primary sodium pump No. 1 had operated essentially without trouble for over 32,000 hr before experiencing difficulties in late 1970. The pump at that time experienced periodic power increases caused by rubbing of the pump shaft. Removal and disassembly indicated that heavy sodium and sodium oxide deposits in and around the lower labyrinth had caused shaft/labyrinth binding, which resulted in the increased power demand.

The equipment for removing the pump had been used previously for both primary pumps in mid-1963. Once again, the procedure and equipment proved satisfactory for removal and reinstallation of the pump.

Once removed, the pump was cooled and disassembled in the reactor building. The disassembly procedure was complicated by the precautions required to prevent spread of radioactive contamination, to restrict radiation exposure of personnel, and to minimize the possibility of radioactive-sodium fires.

Cleaning and decontamination of the pump components were done primarily on an outside sodium-cleanup pad. The pad had not been designed to handle large radioactive sodium components and proved inadequate. Adverse weather conditions and strict regulations to prevent the spread or release of radioactive contamination hampered the cleaning and decontamination operations and significantly added to the cleanup time for the pump.

Inspection during and after disassembly revealed no basic deficiencies in the pump, but showed two areas that required minor corrective modifications. The obvious problem that had caused the pump binding was the deposition of sodium vapor and oxide in and around the lower labyrinth. The labyrinth was badly corroded and required replacement. The drain holes in the baffle were relocated to improve the argon purge around the pump shaft. This corrective measure should help retard the deposition of sodium vapor at the region of the lower labyrinth.

The second problem was the leakage of grease from the grease reservoir for the lower bearing of the drive motor. This reservoir was enlarged and vented to provide better containment of lubricant.

Operation of the pump following reinstallation in the primary tank has been normal. Insufficient operating time has been accumulated, however, to determine if the minor modifications will increase the length of time before the pump must again be removed for maintenance.

It is currently planned to remove primary sodium pump No. 2 for maintenance at the earliest convenient long plant-maintenance shutdown. The experience gained removing and repairing primary sodium pump No. 1 is expected to expedite the work on pump No. 2. The work on pump No. 1 was recorded on videotape for reference and for use in training.

A comparison of conditions will be made between pumps No. 1 and 2. The inspection of pump No. 2 should reveal why this pump did not experience the same operating abnormalities as pump No. 1.

Improved cleaning facilities are expected to be available for cleaning and decontaminating pump No. 2. It appears that the decon cell of the Hot Fuel Examination Facility can be used for this work.

Where the components of pump No. 1 had machined surfaces (of an estimated 63 μ in. or less), the surfaces were cleaned of sodium and decontaminated of radioactivity quite easily, compared to the rough as-cast, as-forged, and as-rolled metal surfaces. The residual radioactivity levels on these machined surfaces were low enough after decontamination so that further work on these surfaces did not have to be done inside a contamination-controlled enclosure.

It is recommended that overall machining be considered for major sodium components in future LMFBR's. The experience with pump No. 1 indicates that the cost savings due to reduced cleaning and decontamination might be greater than the cost of overall machining. The associated time savings and reduction in fire and radiation hazards would also be desirable. On the basis of the experience with pump No. 1, a machined finish of approximately 32 μ in. would be adequate.

APPENDIX A

Cost Analysis for Removal and Repair of Primary Sodium Pump No. 1

	<u>Man-hours</u>	
EBR-II Operations Engineering Surveillance		
Robert E. Seever (Staff)	360	
Bernard C. Cerutti (Staff)	<u>40</u>	
Total		400
EBR-II Operations "Crew E" Maintenance		
Craftsmen	2912	
Foremen	<u>840</u>	
Total		3752
Materials on purchase requisitions		\$ 1,790.35
EBR-II Fuels and Examination Facility (FEF)		
Technicians	80	
Karl H. Kinkade (Staff)	<u>24</u>	
Total		104
Materials on purchase requisitions		350.00
EBR-II Reactor Operations Section		
Technicians (Fireguard)	468	
Training Section (Training Films)	72	
William H. Perry (Staff)	<u>256</u>	
Total		796
EBR-II Coolant Chemistry Section		
D. W. Cissel (Staff)	16	
H. Hurst (Staff)	32	
W. J. Richardson	8	
R. N. Buchanan	8	
D. G. Walters	<u>8</u>	
Total		72
Materials on purchase requisitions		3,143.81
EBR-II Test & Analysis Section		72
EBR-II Analytical Laboratory		202
EBR-II I&C Instrumentation Section		40
Idaho Division--Machine Shop		
Craftsmen		204
Materials and services on purchase requisitions		840.86
Idaho Division--Materials Handling Section		
Craftsmen--Equipment Operations	176	
Idaho Nuclear Corp. Craftsmen	<u>16</u>	
Total		192
Idaho Division--Plant Services		
Labor and materials charged to service request No. 92016		1,681.26
Idaho Division--Radiation and Industrial Safety		
Technicians	1056	
Earl D. Graham (Staff)	32	
Earl M. Cook (Staff)	32	
Junior F. Sommers (Staff)	<u>524</u>	
Total		1644
Materials on purchase requisitions		225.00
Idaho Division--Photo Services		
618 man-hours charged on 61 work requests and materials		7,827.53
Total man-hours expended	<u>7478</u>	
Total requisition charges to inspection of primary pump No. 1		<u>\$15,858.81</u>

APPENDIX B

Details of Disassembly of Primary Sodium Pump No. 1

This appendix gives further details of the containment, support, and handling of pump No. 1 during disassembly in the reactor building. This description is unique to EBR-II and may not be applicable to other LMFBF facilities. At each facility the methods to be used will depend on the pump configuration, radiation levels, and facility design.

1. Pump Containment

The contamination-controlled enclosure was constructed of a wooden frame with polyethylene-film covering, as described in Section V.B.1 and shown in Fig. 23. (The enclosure also appears in Figs. 10, 13, and 22.) The framework had to be built within the confines of the 8 x 8-ft hatch opening in the basement floor. Change rooms were built outside these confines on the basement and subbasement floors. Plexiglas windows were installed in the containment walls for monitoring the disassembly of the pump.

Only two technicians at a time could work efficiently in the enclosure. This was due to the limited space for the pump, technicians, scaffolding, equipment, tools, argon supply, and air supply. The technicians worked in full protective clothing with supplied-air face masks. Two teams of technicians were used, one team working inside the enclosure for about 1 hr while the other team rested and monitored the working team. Occasionally a third member was added to the inside team, when required.

Other members of the work group monitored the air supply, operated the overhead crane, passed tools and equipment in and out of the enclosure, and directed the disassembly work. Telephone communications were maintained between the inside working team, the air-supply monitor, the crane operator, and the work-group supervisor. At least two members kept a constant safety watch on the inside team. One or two health physicists also monitored the work constantly.

The argon supply inside the enclosure was used to slow the sodium-air reactions during disassembly. Occasionally the sodium adhering to a pump surface started to "bubble." When this happened, the technicians wrapped the area with an asbestos blanket and inserted the argon-supply Tygon tube under the blanket with the flow set at 5-10 cfh. This slowed the reaction until the sodium was safely oxidized. This system proved very efficient. It was used once to extinguish a small fire that started within the baffle subassembly. The fire was extinguished within a few seconds, even though there was approximately 75 lb of sodium and sodium oxide inside the baffle.

The maintenance work group and supporting personnel at EBR-II are skilled and experienced in working with sodium components; they have

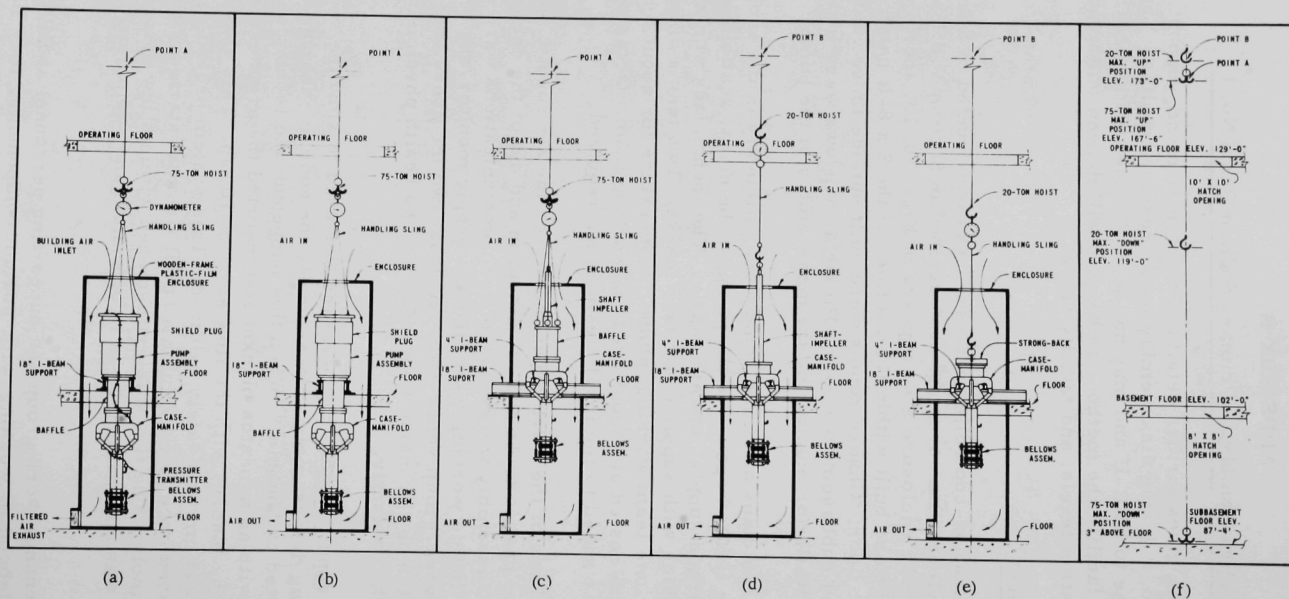


Fig. 23. Containment, Handling, and Support of Primary Pump during Disassembly. (a) Complete pump assembly: first position; (b) complete pump assembly: second position; (c) pump assembly, less shield plug; (d) pump assembly, less baffle; (e) pump assembly, less shaft-impeller; (f) dimensions of work area.

performed this type of work for a number of years. If a group inexperienced in working with sodium components were to perform this type of disassembly, prior training would be recommended. Such training would be necessary to overcome a person's natural apprehension in working with sodium components and would enable him to maintain control of the work during problem periods.

2. Pump Support

The pump assembly was supported at different pump locations during disassembly, as shown in Figs. 23a-23c.

In Fig. 23a, the complete pump assembly (less drive motor and cooling blower) was supported by the bottom flange of the shield-plug sub-assembly, which was set on the two parallel 18-in. I-beams. The I-beams were held in position laterally by two 8-in. channels across each end (channels not shown, for clarity). This position provided access for removing 12 of the 1-in. assembly cap screws holding the baffle to the shield plug.

In Fig. 23b, the complete pump assembly was supported by the bottom side of the top flange of the baffle (where the capscrews were already removed). The flange rested on the 18-in. I-beams. This position provided access for removing the remaining twelve 1-in. capscrews so that the shield plug could be removed.

In Fig. 23c, the pump assembly less shield plug was supported by two 4-in. I-beams inserted through opposite volute-pipe openings of the case-manifold. The two 4-in. I-beams were set across the 18-in. I-beams. This position provided access to remove all the 1-in. assembly capscrews holding the baffle to the case-manifold, and the baffle was then removed.

In Fig. 23d, the pump assembly continued to be supported as in Fig. 23c, allowing the shaft-impeller to be lifted out of the case-manifold and removed.

In Fig. 23e, the method of support remained the same. A strong-back made of back-to-back steel angles was bolted across the top flange of the case-manifold and connected to the hoist for removal. (The 4-in. I-beams were removed when the hoist took the weight of the case-manifold.)

Figure 23f shows the floor levels, the sizes of hatch openings, and the limits of travel for the hoists. With the removal of the entire pump from the work area, the containment was dismantled and removed. The work area was thoroughly cleaned and decontaminated of radioactivity before a new wooden-frame and polyethylene-film enclosure was reinstalled for reassembly of the pump.

3. Pump Handling

Figures 23a-23e also show the rigging for handling the pump during the disassembly stages.

In Fig. 23a, the pump assembly was raised and lowered by a four-legged steel-cable sling connected to the four pump-lifting brackets bolted to the top flange of the shield plug. The sling was connected to a dynamometer, which in turn was connected to the 75-ton hoist of the overhead crane. The dynamometer provided before-cleaning weights during pump disassembly and after-cleaning weights during pump reassembly. These measurements yielded the weight of sodium and sodium oxide adhering to the pump assembly and to each major subassembly.

Figure 23b shows the same handling method as in Fig. 23a. The 75-ton hoist was used to change the pump-support location from the shield-plug flange to the baffle flange for completion of removal of the assembly capscrews. The shield plug was then removed from the pump assembly with the hoist.

In Fig. 23c, the pump assembly was raised and lowered by a four-legged steel-cable sling connected to eyebolts installed in the top-flange assembly holes of the baffle at 90° increments. The sling was connected through a dynamometer to the 75-ton hoist. The 75-ton hoist continued to be used instead of the auxiliary 20-ton hoist because the low speed of the 75-ton hoist (about 2 in./min) was needed for removing the lower end of the baffle from inside the case-manifold.

Figure 23d shows the removal of the shaft-impeller from the case-manifold with a single-leg steel-cable sling connected to an eyebolt threaded into the end of the pump shaft. The sling was connected through a dynamometer to the 20-ton auxiliary hoist. The shaft-impeller was then raised by the hoist out of the case-manifold.

Figure 23e shows a strongback bolted to the top flange of the case-manifold. A single-leg sling was connected to the center of the strongback. This rigging provided the clearance required for later use on the outside cleanup pad, where lift height was limited. An initial lift of about 1 in. was made so that the 4-in. I-beams could be removed from the volute-pipe openings and the 18-in. I-beams could be moved farther apart to prevent possible damage to the bellows as the lift was completed. The case-manifold was then removed with the hoist.

4. Conclusions

The containment, support, and handling of pump No. 1 proved satisfactory for both disassembly and reassembly. The only recommended change

for this type of work would be to remove the pump from the reactor building and perform the disassembly in a maintenance facility. This would remove the potential hazard of sodium-air reactions from the reactor building. If necessary, as at EBR-II, this work can be done in the reactor building. However, in the design of new LMFBR facilities, the methods for removing, disassembling, cleaning, and decontaminating large sodium components should be considered an integral part of the design criteria.

ACKNOWLEDGMENTS

The removal and repair of primary sodium pump No. 1 were a team effort. The number of individuals whose performance was instrumental in the successful performance of the work is too numerous to individually acknowledge. There were, however, some individuals whose contributions were especially significant and therefore deserve special mention. They are:

The Operations Maintenance Crew under J. S. Remsburg for the actual performance of all removal, cleanup, and reinstallation operations.

The Idaho Facilities Machine Shop for fabrication of tools and equipment and for dimensional inspection of pump components.

The Idaho Facilities Radiation and Safety group for radiation surveillance.

The Idaho Facilities Materials Handling group for transporting major pump components to cleanup facilities, etc.

T. R. Spalding for development of procedures for removal, cleaning, and inspection of pump components.

Karl H. Kinkade and Howard Hurst for their efforts associated with decontamination of pump components.

REFERENCES

1. L. J. Koch, H. O. Monson, D. Okrent, M. Levenson, W. R. Simmons, J. R. Humphreys, J. Haugsnes, V. Z. Jankus, and W. B. Loewenstein, *Hazard Summary Report: Experimental Breeder Reactor II (EBR-II)*, ANL-5719 (May 1957).
2. L. J. Koch, W. B. Loewenstein, and H. O. Monson, *Addendum to Hazard Summary Report: Experimental Breeder Reactor II (EBR-II)*, ANL-5719 (Addendum) (June 1962).
3. Argonne National Laboratory, *EBR-II System Design Descriptions*, Volume II. Primary System, Chapter 3: "Primary Cooling System" (Mar 15, 1969).
4. *Reactor Development Program Progress Report: March 1971*, ANL-7798, pp. 12-20 (Apr 19, 1971).
5. C. R. F. Smith *et al.*, *Radioactivity of EBR-II Components: I. FY 1971 Examinations*, ANL-7873 (to be issued).

ARGONNE NATIONAL LAB WEST



3 4444 00023727 1

